U. S. DEPARTMENT OF AGRICULTURE
U.S. Bureau of Agricultural Engineering and Extension Service

TERRACING, THE FIRST STEP IN EROSION CONTROL

By S. P. Lyle, Senior Agricultural Engineer

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It is scarcely necessary to mention to you, the Farm Advisors of the wonderful agricultural State of Illinois, the importance of controlling erosion especially upon cultivated fields. You have seen its devastating effect upon some of the fertile soils of your rolling lands. The Soil Survey Department of this University has mapped the State and measured the problem. Reports from Illinois state that erosion control is of importance on approximately 26,000,000 acres of Illinois farm land. A 1933 estimate gives the following figures for the State:

Destructive erosion in timber land	3,072,000 acres
Serious erosion on pasture and orchard land. .	2,944,000 "
Harmful erosion on crop land.	12,618,000 "
Erosion on lesser slopes of crop land.	16,000,000 "

I have observed the erosion of your farm lands on numerous trips through this State - but why should I dwell upon a situation with which you are familiar through daily contact and experience? Since you are familiar with the problem, you are also doubtless assured of the value of control measures. Some of your cooperators have expressed their personal opinions as follows:

From Williamson County - Terracing has increased land value $10 per acre.
" Randolph County - Received $2 more per acre in 1932 on a 10-acre field terraced.
Two other men estimate the value of their terraces at $6 per acre.
" Brown County - 5-acre pasture terraced for 10 years increased the value of land by one-third.

Citing these cases to you is like "bringing coals to Newcastle," but you will doubtless be interested in the following estimates prepared in Oklahoma and Texas last winter:

Estimated per acre values of terracing

38	Texas county agents, average	$ 7.98
49	" National Farm Loan Assn. secretaries	8.08
8	" farm mortgage institutions	10.54
42	Oklahoma county agents	8.58
24	Members, Oklahoma Farm Real Estate Assn.	9.64
	Average of 161 estimates	$ 8.54

In Alabama the 1932 estimate on the per acre value of terracing was $5.00. I have cited these estimates from southern States because of the longer experience and greater number of cases in that region. My personal observations lead me to believe these estimates are low for land in Illinois.

I am confining my remarks to terracing because you are just beginning to protect with terraces that 12,618,000 acres of crop land in Illinois on which harmful erosion is evident. Terracing is the first effective step in protecting such land from erosion, and you as Farm Advisors are interested in learning about the effectiveness of terracing. I shall endeavor to present my remarks in a way which you may find useful in your county work.

Terracing is a primary factor in the protection of farm land from erosion, since erosion is the result of rainfall running off the land at a rapid rate, and terraces control the rate of run-off. Any factors which lessen the rate of run-off reduce the rate of erosion. The silt carrying capacity of water in irrigation channels is estimated by Kennedy 1/ to be proportional to the 5/2 power of the velocity. If the velocity is doubled, the silt transported will be increased almost six times. The weight of particles which will be rolled by a stream is proportional to the velocity raised to a still higher power. Terraces reduce the capacity of run-off waters to transport soil by reducing the velocity.

Erosion, however, is proportional to the volume as well as the velocity of run-off. Since terraces decrease the total run-off they not only reduce the percentage of silt which the water can carry but also reduce the total volume of surface run-off water and hence reduce the volume of soil losses. The savings in water, soil and plant food are favorable to vegetative growth which is also an important erosion control factor, and in addition is the primary factor in the restoration of soil fertility. Thus we see the importance of terracing as the first

1/ B. A. Etcheverry - Irrigation Practice and Engineering, Vol. II, page 88. A reference to the work of R. G. Kennedy, Executive Engineer, Irrigation Branch, Public Works Department, Punjab, India.

step for farmers to take in protecting cultivated fields from erosion for terraces regulate run-off as soon as they are built and continue to protect the land through seasonal and rotational changes in tillage operations and crops.

Terraces came into use in the southeastern States near the middle of the last century. The early terraces were of the bench type. Later this practice was superseded by the use of hillside ditches and narrow ridge terraces because of lower cost of construction. These in turn were superseded by the Mangum terrace, which as described by Elliott 2/ was "8-feet broad and 12 inches high with a shallow ditch or flat 10 feet wide on the upper side, from which the material from the bank is secured."

Although terraces have been in use in other countries for many hundreds of years as an aid in irrigation and as a protection from erosion, little has been determined experimentally concerning their performance until the beginning of this century.

In 1903 the Division of Drainage Investigations, Office of Experiment Stations, began studies in hillside drainage with terraces and tile drainage, and in 1914 began more exhaustive studies of the use of terraces to reduce the enormous losses resulting from erosion. Studies of run-off from small agricultural areas were also carried on at this time as a parallel study. These studies have been continued from their beginning through the same office of drainage investigations, although the office has been transferred from time to time from the Office of Experiment Stations to the Bureau of Public Roads, and at present is the Division of Drainage and Erosion Control of the Bureau of Agricultural Engineering of the U. S. Department of Agriculture.

As a result of these investigations a type of terrace was developed known as the broad-base, variable-grade terrace. It is broad enough to permit the use of modern field machinery on the crops grown upon it, and high enough to safely control the run-off from excessive rainfall. A variable grade is used on long terraces ranging from little or no grade at the upper end to 6 inches per hundred feet at the lower end, to provide the higher velocities at the lower end required for additional drainage capacity without increase in size of the terrace channel. The familiar Farmers Bulletin, "Farm Terracing," through three revisions, has carried this message of erosion control to farmers for the past 15 years. A summary of the county agricultural agents' reports for the past 10 years shows a total of nearly 13,000,000 acres of terracing done, principally in conformity with the practices recommended in this bulletin. If $8 per acre is a reasonable valuation for terracing, then this 13,000,000 acres terraced in the past 10 years represents an enhanced productive land value of $100,000,000. At present 22 States have erosion control extension programs in which terracing is considered the first essential step in a soil and moisture conservation program.

2/ C. G. Elliott - Engineering for Land Drainage, page 333.

The results of the investigations previously mentioned have been published in reports of the Office of Experiment Stations, in Department Bulletin No. 512, "Prevention of Erosion of Farm Lands"; Farmers Bulletin No. 1234, "Gullies - How to Control and Reclaim Them"; and in Farmers Bulletins 997, 1386 and 1669 comprising the three revisions of "Farm Terracing". Three progress reports have also been published of experiments conducted near Raleigh, N. Car., in cooperation with the North Carolina Department of Agriculture; and "Run-off from Small Agricultural Areas", in Journal of Agricultural Research, Vol. 34, No. 9. The State Extension Services of 15 States have issued bulletins relating to terracing based largely on the above publications.

Investigations of erosion problems were begun in 1929 to improve methods, and to reduce the cost of erosion control. Ten soil erosion experimental farms have been established at Guthrie, Okl., Temple, Tex., Hays, Kans., Tyler, Tex., Bethany, Mo., Statesville, N. Car., Pullman, Wash., Clarinda, Iowa, LaCrosse, Wis., and Zanesville, Ohio, in the order named. Each location was chosen because of its representative regional characteristics of soil, climate, topography, and suitability to typical farming practices. Upon each of these 10 farms, ranging in size from 140 to 300 acres, experiments in soil erosion control are being conducted cooperatively by the Bureau of Agricultural Engineering, the Bureau of Chemistry and Soils, and the State Agricultural Experiment Station.

Since the recent developments from studies at these farms have not been published, I shall present them here as excerpts or abstracts from a recent progress report prepared by the Division of Drainage and Erosion Control of the Bureau of Agricultural Engineering.

Terraces Conserve Soil.

"At Guthrie, Oklahoma, the soil losses from an unterraced area during a two year period averaged 66 tons of soil per acre per year as compared with an average of 2.65 tons of soil per acre from a terraced area, both areas being cropped quite similarly and the average rainfall being about normal for the two year period. That terraces are effective in controlling erosion on the Experimental Farm at La Crosse, Wis. is evidenced by the fact that while terraced land planted to barley lost less than 150 pounds per acre during two rains totaling about 3½ inches, the loss from unterraced land similarly cropped was 3.36 tons per acre or over 49 times as great. The value of terraces in reducing erosion losses on land planted to wheat at Bethany is apparent from the record of soil losses during one rain of 1.17 inches. During this rain only 60 pounds of soil per acre were lost from a terraced area as compared with 2,100 pounds per acre from an unterraced area, 35 times as much soil being lost from the unterraced as from the terraced area."

Half the yield and twice the erosion loss on eroded land.

"The rapid depletion of the fertility of the soil on the Guthrie farm due to soil erosion was manifested by a comparison of crop yields obtained on virgin land first broken when the station was established and badly eroded land that had been in cultivation for over 30 years. Over 40 bushels of oats per acre were produced on the virgin land as compared with about 15 bushels per acre on the badly eroded land. It was found by actual measurements of the soil losses on terraced areas that erosion proceeds nearly twice as fast on badly eroded as on virgin land and by actual cost records that the cost of terracing badly gullied land was over 6 times as much as the cost of terracing virgin land before any gullies had developed.

Soil Losses Increase with Grade of Terraces.

"An experiment on the Guthrie farm where the grades of terraces were level, 2, 4 and 6 inches per hundred feet gave the following soil losses:- 2.65, 4.63, 5.29 and 10.26 tons per acre respectively. The terrace with the 6 inch grade lost about 4 times as much soil as the level terrace and about twice as much as the terraces with the 2 and 4 inch grade. The results at Guthrie were corroborated by experiments at Bethany where the soil losses increased from 0.63 tons to 7.27 tons per acre for terraces with grades as follows:- Level, 2 inches, 4 inches, 6 inches and 8 inches per 100 feet. Appreciable scouring in the channels with 6 and 8 inches fall per 100 feet was plainly visible at both Guthrie and Bethany. At Guthrie both years the yields of cotton and corn were less for the level terrace and for the terrace with a 6 inch grade and it appears that the smaller yield in the level terrace channel is due to partial drowning of the crop and in the 6 inch graded terrace channel to the washing out of some of the small plants due to the high velocity of the water. From these results it appears that sufficient grade should be given a terrace to provide satisfactory drainage of the terrace channel and yet not so large a grade as to cause appreciable erosion.

Superiority of Variable Graded Terraces.

"The relative merits of a variable and uniform graded terrace has been a much discussed subject. Experiments designed to collect data for the purpose of comparing these two types of terraces are being conducted on several of the soil erosion farms. A variable graded terrace has a grade which increases from the upper to the outlet end of the terrace. The principle of the variable graded terrace is that the upper end of the terrace with a small grade tends to store or hold back the run-off water until the water below where the grade is greater has a chance to flow off thus preventing the piling up or concentration of the water near the outlet end of the terrace which often results in a terrace break.

"The terraces on the Tyler farm, one with a uniform grade of 6 inches per 100 feet and the other with a variable grade of 0 to 6 inches per 100 feet lost an average of 7.95 and 6.8 tons of soil per acre respectively annually for a two year period, the uniform graded terrace losing 17 per cent more soil than the terrace with the variable grade. Two other terraces 1,700 feet long, one with a uniform grade of 3 inches per 100 feet and the other with a variable grade of 0 to 3 inches per 100 feet lost an average of 5.15 tons and 4.15 tons of soil per acre respectively, the uniform graded terrace losing 19 per cent more soil than the variable graded. A terrace on the Bethany farm with a uniform grade of 4 inches per 100 feet lost 31 per cent more soil than a terrace with variable grade of 1 to 4 inches per 100 feet. These results show a consistent tendency to smaller soil losses from the variable than from the uniform graded terraces, which justifies giving preference to the use of the variable graded terrace."

Short Terraces Preferable to Long.

"Long terraces showed a greater soil loss than short terraces on the Tyler farm. A terrace 700 feet long with a vertical spacing of 4 feet and a uniform grade of 3 inches per 100 feet showed average annual soil loss for a two year period of 3.55 tons per acre as compared with 4.85 tons per acre for a terrace 1,700 feet long with the same spacing and grade. It is believed that the greater volume of water in the terrace channels of the longer terraces causes more erosion and carries away more soil that has moved down the slope into the terrace channel. From these results it appears that short terraces are to be preferred to long terraces and should be used wherever the controlling conditions permit."

How Terrace Spacing Affects Soil Losses.

"Variations in the results of the terrace spacing experiments on the different farms make it rather difficult to arrive at any definite conclusions with regard to spacing terraces. An experiment at Tyler, Texas, consisting of three terraces 1,700 feet long and with vertical spacings of 3, 4 and 5 feet gave soil losses increasing with the spacing of the terraces during two successive years when the terraces were planted to cotton and corn. The average annual soil losses in tons per acre were 3.17, 4.83 and 5.16 tons respectively. Similar results were obtained on the Guthrie project for terraces 700 feet long and with spacings of 2, 3½ and 5 feet when soil losses of 2.74, 3.96 and 4.98 tons per acre respectively were obtained when the terraces were planted to corn in 1931. The next year when these same terraces were planted to oats the soil losses were about the same regardless of spacing. It appears that this difference in the results was due to the development of small gullies on the wider spacings when in corn and the absence of such gullies when in oats. The results at Guthrie seem to indicate that soil losses increase with the spacing of the terraces when the ground is bare, fallow or cropped to clean cultivated row crops and are not much affected by the

spacing when the land is cropped to close growing grain crops. Results at Tyler and Bethany for short terraces planted to cultivated crops do not verify the above conclusions since there were no large differences in the soil losses at Tyler for terraces 700 feet long with different spacings and for two sets of terraces 700 and 1,040 feet long with different spacings at Bethany. Conditions on the various terraces in the Guthrie experiment are quite uniform and the experiment is duplicated so more weight is given to the results of the Guthrie experiment. Uniformity in conditions of terraces in an experiment improve with age and it is felt that additional data will be required at both Tyler and Bethany for short terraces before definite conclusions with regard to spacing can be formulated.

"Observations indicate that gullying between terraces is much worse for the wider spacings and as a result the accumulation of soil is greater in the terrace channel. This greater deposit of soil in the channel of the terrace with wider spacing would tend to result in greater soil losses for wider spacing especially for long terraces since the volume of water removed by long terraces particularly near the outlet end is much greater than for short terraces and also the water moves off at a greater velocity which is sufficient to carry away a large amount of soil deposited in the terrace channel. Since the velocity of the water also increases with the grade of the terrace, no doubt the greater the grade of the terrace the more pronounced will be the increase of soil losses with increase in terrace spacing particularly for long terraces.

Level Terraces Holding All Rainfall Not Satisfactory.

"Experiments with level terraces at Tyler, Temple, Guthrie and Bethany where all of the rain is retained above the terraces to increase moisture supply for crops indicate that this practice is not advisable in regions of high annual rainfall and tight soils. While this practice has resulted in increased crop yields of from 25 to 40 per cent in the western part of Texas and Oklahoma where the annual rainfall is light and the soil is comparatively open, it was found on the Guthrie farm that damage done to an oats crop by water standing above the terraces resulted in a decreased yield of 60 per cent and somewhat similar results were obtained at the Tyler, Temple and Bethany stations. Similar level terrace experiments are included in the program of all of the experimental farms, the results of which will afford an index for comparing the rate of percolation of water into the different soils in addition to data on the beneficial or deleterious effect of conserving all of the moisture for crop production.

Terracing Steep Slopes.

"It has generally been considered inadvisable to attempt to terrace slopes for cultivable purposes greater than 12 to 15 per cent. However, it is desired to obtain definite information with regard to this matter so that much steeper land has been terraced on several of the Federal farms.

On the farm at LaCrosse, Wisconsin, cultivated slopes of 25 per cent and pasture slopes of 30 per cent have been terraced and so far the results of this terracing work have been quite satisfactory. At the Pullman farm in the Palouse region of Washington cultivated slopes as high as 40 per cent have been terraced. However, erosion in that region is caused by light rains and rapidly melting snows and results obtained in that country on steep slopes would not apply to similar slopes in the middle west.

Machinery on Terraced Land.

"On lands of minimum slope, wide terraces constitute the most satisfactory solution of the machinery problem; on lands of moderate slope, the width of terrace is limited, to a certain extent, by the greater cost of construction; and, on steep slopes, it is practically impossible to build a terrace wide enough to meet satisfactorily the requirements of all existing machinery.

"In regions where the use of single-row horse-drawn machinery is economically sound and is expected to continue, the machinery problem is negligible provided farming operations are conducted parallel to the terraces, which is generally the prevailing practice.

"In regions where two-row tractor-drawn machinery predominates or is rapidly supplanting the one-row equipment, the machinery problem is perhaps the most acute at the present time. On the more moderate slopes the crossing of terraces with machinery is commonly practiced while on the steeper slopes the farm operations are generally conducted parallel to the terraces although some farmers adhere to the same practice in laying out rows regardless of slope. If all farmers would adopt the method of running rows parallel to the terraces the machinery problem would be greatly simplified.

"Considerable experience has been gained from observations of the operation of machinery over terraced land on the several soil erosion experiment farms established by the U. S. Department of Agriculture. A separate paper would be required for a detailed discussion of this subject. While on this subject, however, attention is directed to the fact that terracing often improves fields for the smoother operation of farm machinery. Gullied fields are a source of great annoyance to the farmer in movement of farm machinery and often they are necessarily farmed in sections between gullies that cannot be crossed with machinery or only at the risk of serious damage to the machines. If the gully cannot be crossed, not only the land occupied by the gully itself is lost to cultivation but also a strip on each side cannot be successfully farmed. Terracing such a field reclaims all of the land for cultivation and facilitates the satisfactory use of farm machinery.

Comparing Erosion Losses of the South and North.

"It is difficult to make accurate comparisons of the damage done by soil erosion on the various soil erosion farms owing to the differences in the fertility and depth of surface soil, annual rainfall, intensities of rain, season of heaviest rainfall, topography, crops and farming practices. Satisfactory comparisons could only be made after experimental results have been obtained on all of the farms for a period of years. The prevailing general opinion has been that soil erosion is much more destructive and injurious to agricultural lands in the south than in the north. Results so far obtained at Bethany seem to challenge the validity of this opinion since the record of soil losses on corn land for the year 1931 at Bethany with cotton land at Guthrie indicate larger soil losses at Bethany than at Guthrie for the year 1931 and about the same for the year 1932. The rainfall at Bethany for the year 1931 was above normal while at Guthrie it was below normal for the year 1931 and above normal for the year 1932, which as stated above makes it rather difficult to arrive at an accurate comparison. However the financial value of the losses from soil erosion are no doubt larger at Bethany than at Guthrie particularly when the far greater fertility value of the Bethany soil is considered. Hence the landowner in this region should be even more concerned than the southern farmer about his enormous annual soil losses that will in a comparatively short time result in the removal of practically all the fertile top soil."

SLIDE SERIES TO ILLUSTRATE

TERRACING - THE FIRST STEP IN EROSION CONTROL

By S. P. Lyle
Senior Agricultural Engineer
U. S. Department of Agriculture.

1. Slide No. 59 - Advanced Erosion
2. " " 60 - Erosion in the South
3. " " 24 - Erosion in the Midwest
4. " " 18 - " " " "
5. " " 17 - " " " "
6. " " 65 - Alluvial Deposit from Erosion
7. " " 3 - " " " "
8. " " 54 - Terraces in the Philippine Islands
9. " " 35 - Bench Terraces
10. " " 63 - Broad-base Terraces
11. " " 25 - Level Terraces
12. " " 29 - Building Terraces
13. " " 42 - " "
14. " " 45 - Completed "
15. " " 66 - Terraces Controlling Run-off
16. " " 57 - " after the Run-off
17. " " 43 - Snow Drifts
18. " " 47 - Outlet Baffles
19. " " 40 - Protected Drain Channel
20. " " 39 - Spillways
21. " " 4 - The Gully
22. " " 32 - Silt Boxes on Erosion Study Farms
23. " " 10 - Silt Deposit in Silt Box
24. " " 41 - Measuring Losses on Erosion Study Farms
25. " " 44 - Straight Rows on a Terraced Field
26. " " 34 - Contour Rows " " " "
27. " " 12 - Young Orchard Terraced
28. " " 33 - Wheat on a Terraced Field
29. " " 27 - Binding Wheat on a Terraced Field
30. " " 30 - Harrowing in Terraced Field
31. " " 36 - Drilling Wheat on a Terraced Field
32 " " 1 - The Field Gully Becomes a Field Boundary
33. " " 2 - Finger Gullies Cutting up a Field
34. " " 26 - A Reclaimed Gully Area